



Reclamation Guidelines

For Surface Mined Land in Southwest Virginia

POWELL RIVER PROJECT

Revegetation Species and Practices

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Establishing vegetation is an important activity in reclaiming mined lands. A vigorous vegetative groundcover is essential to control soil erosion on mined areas. Revegetation encourages minesoil development, creates an aesthetically pleasing landscape, and contributes to productive postmining land use. Prompt and thorough establishment of vegetation after mining is essential to compliance with the federal Surface Mining Control and Reclamation Act (SMCRA) by coal-mining operations.

This chapter summarizes procedures for establishing vegetation on mined areas. The emphasis is revegetation to control erosion and establish hayland-pasture as a postmining land use. Powell River Project has developed a separate set of recommendations for revegetation to establish trees and shrubs for a forested postmining land use; these are reviewed in Virginia Cooperative Extension Publication 460-123, *Restoring Forests on Surface Mined Land*.

Minesoil Selection and Placement Procedures

Successful revegetation of active surface mines begins well in advance of fertilization and seeding. The most important step, by far, in surface-mine revegetation occurs when the soil medium is selected and placed on the land surface. For optimum plant growth, the soil medium should be

selected to provide physical and chemical properties suitable for the intended postmining land use.

Fertilization and, in some cases, liming are also important components of revegetation procedures. Minesoil selection, placement, and amendment procedures are covered in VCE Publication 460-121, *Creation and Management of Productive Minesoils*.

Plant Species for Revegetation

When establishing vegetative groundcover on surface mined sites, the two most important factors influencing species selection should be soil properties and the postmining land use. Three general categories or types of plants are used for revegetation of mined areas: grasses, forbs, and trees.

Grasses are the most commonly seeded plants in revegetation programs. They belong to the *Gramineae* family, produce large amounts of biomass, and are adapted to initiate regrowth rapidly after mowing or grazing. Grasses have fibrous root systems which hold soil in place, thereby controlling erosion.

Forbs - herbaceous flowering plants - are generally used in mine revegetation in conjunction with grasses. Forbs usually have broad leaves, flowers, and a branching taproot system. Forbs can be further classified as *legumes* and *nonlegumes*.

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Legumes are forbs that belong to the *Leguminosae* family. Legumes are especially important for revegetating mined lands because they are capable of using nitrogen (N) from the air to meet their N nutrition requirements, and they can transfer this “fixed” N to other components of the plant/soil system. A healthy population of legumes is essential to successful revegetation, especially on minesoils constructed from blasted overburden (“topsoil substitutes”), which are essentially devoid of native plant-available N (see VCE Publication 460-121).

Nonleguminous Forbs are also broad-leaved plants with showy flowers. Examples of nonleguminous plants used in revegetation are buckwheat (*Fagopyrum sagittatum*), sunflowers (*Helianthus spp.*), and Japanese fleecflower (*Polygonum cuspidatum*).

Trees and Shrubs are the final plant-material category. They are used when forested or wildlife habitat land uses are desired after mining. The establishment of trees and shrubs on mined lands is not discussed in this chapter (see VCE Publication 460-123).

Grasses

Grasses are the most commonly seeded plants in mine revegetation programs for several reasons. First, numerous grass species are available for seeding. Second, seed of grass species adapted to disturbed areas can be obtained readily and at reasonable costs. Third, the grass family (when taken as a whole) is tolerant of a wide variety of environmental and soil conditions.

Several grasses are well adapted to the infertile, droughty, and/or acid sites often associated with mined areas; others are able to provide high-

Table 1. Grasses available for seeding in mine revegetation, eastern U.S.

Common Name (<i>Scientific Name</i>)	Principal Cultivars	Life Cycle ¹	Growth Season ²	Origin ³	Seeding Rate Lbs./ac ⁴	Ease of Establishment	Persistence
Kentucky Bluegrass (<i>Poa pratensis</i>)	Numerous turf varieties	P	C	I	15-20	Fair	Fair
Smooth Brome (<i>Bromus inermis</i>)	Saratoga, Lincoln, others	P	C	I	10-15	Fair	Fair
Deertongue (<i>Panicum clandestinum</i>)	Tioga	P	W	N	10-15	Fair	Good
Tall Fescue (<i>Festuca arundinacea</i>)	Kentucky31, Johnstone, Alta, Forager, Kenhy, Phyter, Athens	P	C	I	10-20	Good	Good
Weeping Lovegrass (<i>Eragrostis curvula</i>)	Morpa	P	W	I	2-5	Good	Fair
Orchardgrass (<i>Dactylis glomerata</i>)	Pennlate, Hallmark, Potomac, others	P	C	I	10-20	Good	Fair
Redtop (<i>Agrostis gigantea</i>)	Common	P	C	I	5-10	Fair	Good
Perennial Ryegrass (<i>Lolium perenne</i>)	Numerous cultivars	P	C	I	10-15	Good	Fair
Switchgrass (<i>Panicum virgatum</i>)	Cave-in-Rock, Blackwell, Kanlow	P	W	N	2-5	Fair	Good
Timothy (<i>Phleum pratense</i>)	Bounty, Champlain, Clair, Timfor	P	C	I	5-10	Fair	Fair

¹ P - perennial, A - annual, B - biennial

² C - Cool Season, W - Warm Season

³ N - Native, I - Introduced

⁴ Seeding rate when species is used alone; should be reduced when species is used in mixtures.

quality hay and forage. A healthy grass component is important to successful erosion control. Many species are capable of producing large amounts of biomass in a short time and responding quickly to fertilizer and management, while other species may be slower growing and persist on the site for long periods without management. For these reasons, a good revegetation program will always contain grasses as a major component of the seed mix.

Grass species commonly used in mine reclamation are listed in Tables 1 and 2. For each, the most commonly used varieties and cultivars, and other characteristics essential to successful use in reclamation, are also summarized. The term “cultivar” is derived from the term *cultivated variety*. Some cultivars have distinguishing characteristics that make them better adapted to the environmental conditions on Appalachian mined areas. The

plant’s life cycle, season of growth, origin, seeding rate, and soil/site tolerances are also shown.

Grasses for Groundcover and Forage:

Tall Fescue is a cool-season grass which is grown throughout the eastern United States. The range of tall fescue extends from Florida to Canada; the species is common in Kentucky, Virginia, West Virginia, Ohio, and Pennsylvania. It is a deep-rooted, long-lived perennial that gradually develops into a uniform sod in older stands.

Well-established tall fescue provides excellent erosion control, and this species is widely used in mine reclamation throughout the eastern U.S. It grows best in well-fertilized, loamy soils, but it is capable of persisting under a wide variety of soil and environmental conditions. Tall fescue grows well if the pH is 4.5 or above; the species is drought-resistant and cold-tolerant.

Drought Resistance	Cold Tolerance	Acid Tolerance	Salt Tolerance	High Water Toler.	Lower pH Limit	Comments
Poor	Good	Fair	Fair	Fair	5.5	Shallow rooted sod-former. Good palatability
Good	Good	Poor	Good	Fair	5.0	Forms dense sod. Good erosion control.
Good	Poor	Good	Fair	Fair	4.0	Acid tolerant, drought resistant.
Good	Good	Good	Good	Fair	4.5	Most commonly seeded grass on mined areas. Drought resistant.
Good	Fair	Good	Fair	Fair	4.0	Tolerant of acid minesoils and dry conditions.. Short lived perennial.
Good	Good	Fair	Fair	Fair	4.5	Develops rapidly and long lived. Used in wildlife plantings
Good	Good	Good	Good	Good	4	Sod former. Adapts to a wide variety of soils. Short lived if not managed.
Poor	Good	Poor	Fair	Fair	4.5	Short lived perennial. Dominates stands for 2 years.
Good	Good	Good	Fair	Good	4	Rhizomatous, acid tolerant, tall. Slow to establish.
Fair	Poor	Good	Good	Fair	4.5	Good quality hay and pasture. Does not tolerate heavy grazing. Fertility demanding.

Tall fescue is an excellent reclamation species when a hayland-pasture postmining land use or rapid and thorough erosion control is intended. Due to infection by a fungus (*Acremonium coenophialium*), some varieties of tall fescue can cause problems for grazing animals at certain times of the year. Seeding endophyte-free tall fescue will help minimize problems for cattle if the area is grazed. However, endophyte-free tall fescue is less hardy, less insect-, disease-, and drought-resistant, and less persistent than the nonendophyte-free varieties.

Orchardgrass is a cool-season grass that can be grown successfully on acidic disturbed soils in areas where lime and fertilizer have been applied. It grows from the Gulf States to southeastern Canada. Other than bluegrass (*Poa sp.*), it is probably the most common forage species in the Appalachian region. Orchardgrass is shade-tolerant, and it will persist on shallow, infertile soils. However, it responds to fertilization and is most vigorous when adequate nutrients are available. It is extensively seeded in revegetation mixtures in the eastern U.S.

Redtop grows well throughout the eastern U.S. It tolerates acid soils, clayey soils of low fertility, and poorly-drained soils. Redtop is also shade tolerant

and will produce an effective cover, but it is short-lived.

Timothy is a cool-season species adapted to cooler climates of the Appalachian region. It grows on acidic soils and produces a good sod for erosion control on disturbed areas. Timothy is primarily grown for hay and grows well with seeded legumes.

The Ryegrasses, both perennial and annual, are cool-season species that are commonly used in reclamation seeding mixtures throughout Appalachia. They are very competitive and are an important component for pasture mixtures. Perennial and annual ryegrasses are often used to establish a vegetation cover for soil protection during the winter. They grow on a wide variety of soil types but generally require fertilizer additions.

Kentucky bluegrass is commonly used in pastures on nonreclaimed sites and has been used successfully in mine reclamation. Bluegrass will not persist under low-fertility or low-moisture conditions. When seeded in combination with tall fescue, bluegrass will not persist unless the site is grazed or cut regularly. Therefore, bluegrass is best used in reclamation only on sites that will be actively managed as hayland or pasture.

Table 2. Fast-growing annual grass species used as “nurse crops” in eastern U.S. mine revegetation

Common Name (<i>Scientific Name</i>)	Principal Cultivars	Life Cycle ¹	Growth Season ²	Origin ³	Seeding Rate Lbs./ac ⁴	Ease of Establishment	Persistence
Foxtail Millet (<i>Setaria italica</i>)	German	A	W	I	20-30	Good	Poor
Japanese Millet (<i>Echinochloa crusgalli</i>)		A	W	I	20-30	Good	Poor
Pearl Millet (<i>Pennisetum americanum</i>)	Gahi-1, Starr	A	W	I	15-20	Good	Poor
Oats (<i>Avena sativa</i>)	Noble, Otee, Ogle, others	A	C	I	30-50	Good	Poor
Winter Rye (<i>Secale cereale</i>)	Balbo, Abruzzi, Arostook	A	C	I	30-50	Good	Poor
Annual Ryegrass (<i>Lolium multiflorum</i>)		A	C	I	5-10	Good	Poor
Sudangrass (<i>Sorghum sudanense</i>)	Piper, Common	A	W	I	20-30	Good	Poor
Winter Wheat (<i>Triticum aestivum</i>)	Feland, Severn, Tyler, Wheeler, others	A	C	I	30-60	Good	Poor

^{1,2,3,4} See Notes for Table 1

Weeping Lovegrass is a nonnative grass species which has proved adaptable to low-fertility surface mine sites. It is a perennial warm-season bunchgrass with an extensive but shallow fibrous root system. Weeping lovegrass' native habitat is East Africa, and it grows well during hot and dry climatic conditions. It is one of the fastest germinating grass species. Weeping lovegrass is easy to establish on disturbed land areas, as it grows well on acidic soils (pH as low as 4.0) and tolerates droughty soil conditions. A common use for lovegrass in reclamation is erosion-control on harsh previously mined sites. On the more favorable sites that are generally produced by modern reclamation in Virginia, other grass species will be more productive and — in most respects — more desirable.

Switchgrass is a warm-season grass species that is native to the eastern U.S. It is a perennial bunch grass which spreads through rhizome extension and seed dispersal. If it is not grazed or cut, this deep-rooted grass species grows from 3 to 7 feet tall. Major uses are pasture, hay, soil stabilization, and wildlife habitat improvement. Switchgrass can thrive on relatively dry sites.

Use of Grasses as “Nurse Crops”:

Several fast-growing annual grass species are used

commonly in reclamation seeding (Table 2).

Wheat, Oats, and Rye are cool-season annual grasses adapted to a wide range of soil conditions. Oats and rye are more adapted to infertile soils than wheat. **The Millets** and **Sudangrass** are warm-season, annual grasses. Warm-season annuals can be seeded and will establish during the hot, dry conditions of the summer months, while the cool-season annuals are seeded during spring and fall. Foxtail millet, Japanese millet, and Pearl millet all establish rapidly and form a complete vegetation cover. Their seed is an excellent source of food for wildlife and birds.

Fast growing, annual species (such as oats or millet) may be included in reclamation seed mixes as companions to perennial grasses and forbs. These fast-growing annuals are often called “nurse crops” because they provide protection for the perennial species which are typically slower to establish. The nurse crop grows up rapidly, thus shading the perennials. When the nurse crop dies back, it provides a protective mulch. As the nurse-crop tissue decomposes, nutrients that had been taken up from the soil by the nurse crop become available for use by the other species present. Nurse crops are most beneficial when seeding conditions (either the time of seeding, or soil conditions) are less than ideal.

Drought Resistance	Cold Tolerance	Acid Tolerance	Salt Tolerance	High Water Toler.	Lower pH Limit	Comments
Fair	Poor	Fair	Fair	Good	4.5	Rapid establishing, temporary crop. Seed in summer.
Poor	Poor	Fair	Fair	Good	4.5	Quick, temporary cover. Food for wildlife.
Poor	Poor	Good	Fair	Good	4.0	Fast growing, tall, annual. Food for wildlife.
Fair	Fair	Fair	Fair	Poor	4.5	Quick, temporary crop.
Fair	Fair	Fair	Fair	Poor	4.5	Suitable for cover crop. Provides quick temporary cover.
Poor	Good	Poor	Fair	Fair	4.5	Good winter annual. Outcompetes perennial grasses.
Good	Poor	Fair	Fair	Poor	4.5	Temporary, quick cover. Seed during summer.
Fair	Fair	Fair	Fair	Poor	4.5	Similar to rye.

Legumes

The family of plants termed legumes (Leguminosae) make up a large group comprising approximately 20,000 species. A healthy and persistent legume component is important to N fertility on mine soils. Legumes remove N from the air for their own nutrition; their presence increases the amount of soil N available to companion species.

Nitrogen Fixation:

Legumes fix atmospheric N because they form a symbiotic association with bacteria of the genus *Rhizobium*, which infect the roots to form nodules where they grow and proliferate (Figure 1). Once the symbiotic bacteria become established in the nodules, they produce an enzyme called nitrogenase which allows the nodule to “fix” (or remove) N gas from the atmosphere. The fixed N can be

incorporated into plant proteins. Thus, legumes are able to grow on soils with little available soil N. The plant, in turn, supplies the bacteria in the nodule with energy and carbohydrate for continued proliferation and nitrogen fixation. The association is “symbiotic” because it is beneficial for both organisms.

The presence of vigorous and persistent legumes is important to success in mine land revegetation. Legumes can grow in soils that contain little or no plant-available nitrogen. Legumes aid rehabilitation of disturbed areas by adding fixed atmospheric N available for use by other plants.

Legumes are especially critical in postmining land uses such as unmanaged forest or wildlife habitat, where postestablishment fertilization is not an allowable management practice under SMCRA.

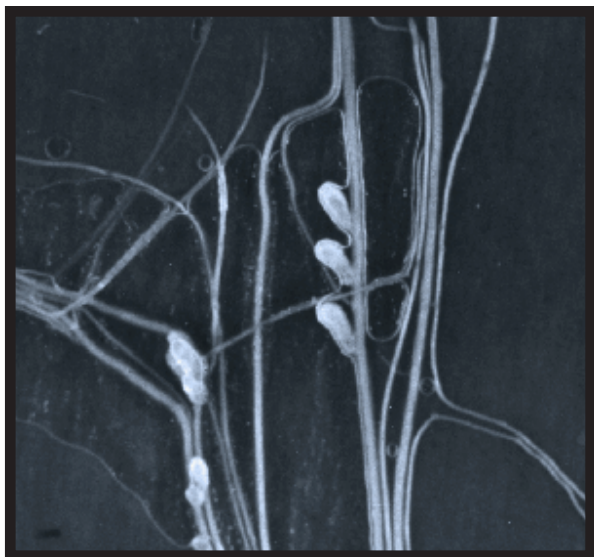


Figure 1. Nodules formed by *Rhizobium* bacteria on the roots of red clover (*Trifolium pratense*). The upper left photo is a close up of nodules in the lower right portion of the lower photo. When *Rhizobium* bacteria are present, legumes can fix nitrogen from the air, satisfying their own N-nutrition requirements and providing excess N to non-legume plant species present.



Where topsoil substitutes (blasted overburden) are utilized to construct minesoils, unfertilized overburden is essentially devoid of plant-available N. Fertilization can remedy this problem, but only in the short term. Beyond the first few years after fertilization, the vast majority of the fertilizer N has been either taken up by plants or carried away (“leached”) by the water that has moved through the soil. Therefore, during the latter stages of the five-year reclamation-success period mandated by SMCRA, organic matter in the soil must serve as the primary source of soil N for the nonlegume species. The soil’s organic matter is made up of dead plant tissue. Nitrogen removed from the soil by plant uptake can be “recycled” as the vegetation dies and decays, but legumes are the only plant component capable of supplying the “new” nitrogen that will be needed to support the continued growth and development of the plant community.

Legume Species Used in Reclamation:

Several forage legumes have been grown successfully on mined lands in the eastern U.S. Table 3 lists forage legumes generally available for use on disturbed areas and gives general characteristics for each. The table also shows the common and scientific name, principal cultivars, and other characteristics. A few of the more important legumes are described in more detail below.

Alfalfa is probably the best known and widely-used forage legume in the U.S. It grows well on a wide range of soils, and in a variety of climates, but alfalfa requires good soil fertility (especially phosphorus, calcium, and potassium), near-neutral pH, and excellent soil drainage. Effective use of alfalfa for mine reclamation in the Appalachians will be limited to only the most fertile and favorable minesoil conditions. Alfalfa produces high amounts of biomass by itself or in mixtures, and has a deep, taproot system which makes it somewhat drought resistant. Because of its long taproot, alfalfa is not well adapted to compacted soils. Due to its high fertility requirements, alfalfa is not likely to do well over the long term as an unmanaged land use component.

Birdsfoot Trefoil is a common forage legume that is often seeded with Kentucky-31 tall fescue on surface-mined lands in Appalachia. It grows on poorly-drained, droughty, infertile, acid, and even alkaline soils. Birdsfoot develops a deep, taproot system with lateral roots and is useful for erosion control and forage. In some cases, birdsfoot does not establish until a year after the initial seeding. When it does establish successfully, birdsfoot trefoil is typically a durable legume species which provides an excellent erosion-control cover. The Fergus variety has proved to be well adapted to Virginia coalfield conditions.

Red Clover is an important legume in the north-eastern U.S. Red clover is used for hay, pasture, soil improvement, and erosion control. It has a deep taproot, but it also maintains a branching root system near the surface. Red clover should be seeded with long-lived grasses and more persistent legume species, because it tends to die back after two years. Like most legumes, it grows best where high amounts of phosphorus (P) and calcium (Ca) are present in the soil.

White Clover is used widely throughout the eastern U.S. for pasture and in disturbed land seeding mixtures. It is almost always seeded with a companion grass, and has a deep taproot system that may or may not persist from year and year.

Ladino is a cultivar of white clover that is widely used in reclamation seeding.

Crownvetch has become a widely-used perennial legume for seeding disturbed lands because it provides continuous, maintenance-free cover for erosion control. It is used on roadbanks and other sites highly susceptible to erosion. Plants can be established by seeds, rhizomes, or crowns. Crownvetch is slow to establish, but after the first year, it will gradually increase its density and may suppress associated vegetation three to four years after initial establishment. It has a deep penetrating taproot with many lateral branching roots. Crownvetch should always be seeded with other rapidly establishing and competitive grasses or legumes.

Table 3. Legumes available for use in eastern U.S. mine reclamation.

Common Name (<i>Scientific Name</i>)	Principal Cultivars	Life Cycle ¹	Growth Season	Origin ²	Seeding Rate Lbs./ac ³	Ease of Establishment	Persistence
Alfalfa (<i>Medicago sativa</i>)	Pioneer 524 Hi-Phy, Classic* DeKalb 120* Saranac AR* Arc Vernal	P	Cool	I	15-20	Fair	Good
Crimson Clover (<i>Trifolium incarnatum</i>)	Dixie Auburn	A	Cool	I	10-15	Good	Fair
Red Clover (<i>Trifolium pratense</i>)	Arlington* Mammoth, Midland Lakeland, Kenland* Pennscott, Norlac Kenstar*	P	Cool	I	10-12	Good	Fair
White (Ladino) Clover (<i>Trifolium repens</i>)	Ladino* Merit, Pilgrim	P	Cool	I	1-5	Good	Good
Alsike Clover (<i>Trifolium hybridum</i>)	Aurora	P	Cool	I	3-5	Good	Good
Crownvetch (<i>Coronilla varia</i>)	Penngift* Chemung* Emerald	P	Cool	I	1-5	Fair	Fair
Flatpea (<i>Lathyrus sylvestris</i>)	Lathco	P	Warm	I	25-30	Poor	Fair
Common Lespedeza (<i>Lespedeza striata</i>)	Kobe* Tenn. 76	A	Warm	I	10-15	Good	Fair
Sericea Lespedeza (<i>Lespedeza cuneata</i>)	Interstate, Serala, Caricea, Appalow** Aulotan**	P	Warm	I	10-20	Fair	Fair
White Sweetclover (<i>Melilotus alba</i>)	Spanish Evergreen Cumino, Hubam, Polara	B	Cool	I	5-10	Good	Fair
Yellow Sweetclover (<i>Melilotus. officinalis</i>)	Madrid, Goldtop, Yukon	B	Cool	I	5-10	Good	Fair
Birdsfoot Trefoil (<i>Lotus corniculatus</i>)	Fergus*, Empire* Cascade, Granger, Tana, Viking*, Douglas, Mansfield, Dawn, Norcen*	P	Cool	I	10-15	Good	Fair
Vetch, hairy (<i>Vicia villosa</i>)		A	Cool	I	20-30	Good	Fair

¹P - perennial, A - annual, B - biennial

²N - Native, I - Introduced

³ seeding rate when used alone; can be reduced when used as component of seed mixture.

⁴ For good growth; some species can persist at lower soil pH.

* Commonly used cultivar **Nontraditional cultivars

Drought Resistance	Cold Tolerance	Acid Tolerance	Salt Tolerance	High Water Toler.	Precip. Range (in.)	Lower pH Limit⁴	Comments
Good	Good	Poor	Fair	Fair	15-20	6	Minesoil pH must be maintained above 6. P needed in high quantities. Good drainage required. Intolerant of low soil pH.
Poor	Good	Fair	Fair	Fair	14-50	5.0	Winter annual legume. Reseeds itself. Tolerates pH to 4.0.
Poor	Good	Fair	Fair	Fair	20-50	5.0	Used for erosion control. Short-lived perennial, but reseeds itself. Requires high P levels. Found on minesoils at pH 4.5
Poor	Fair	Fair	Fair	Good	18-45	5.5	Sod-former. Used in pasture mixtures for erosion control, soil improvement, and wildlife. P and Ca levels critical.
Fair	Poor	Good	Good	Good		5.0	More tolerant of moist, acid soils than other clovers.
Poor	Fair	Fair	Fair	Fair	18-45	5.0	Generally slow to establish. Commonly seeded with ryegrass or rapid establishing species. Found on mines with pH 4.5
Good	Good	Good	Fair	Fair	20-50	4.5	Slow establishment, but has hardy rhizomes. Drought & acid resistant.
Fair	Fair	Good	Poor	Fair	25-45	4.5	Forage legume under trees. Establishes quickly and reseeds itself. Tolerates acid soils.
Fair	Fair	Good	Fair	Fair	25-50	4.5	Tolerates low fertility. Long term erosion protection. Traditional cultivars tend to choke out other vegetation, become woody after first year.
Good	Good	Poor	Fair	Fair	14-40	5.5	Grows in early spring. Has a large taproot.
Good	Good	Poor	Fair	Fair	14-45	5.5	More drought tolerant and competitive than white.
Fair	Fair	Good	Good	Fair	18-45	4.5	Grows well in mixtures. Nonbloating and rhizomatous. Found on minesoils with pH 3.5
Fair	Good	Good	Good	Fair	20-50	5.5	Fall plant for good winter cover. Can be pastured. Important to inoculate.

Flat pea is a long-lived, viney legume that provides good ground cover. Establishment is slow but, once established, it suppresses other vegetation. It is drought resistant and tolerant of acidic soil conditions. Flat pea is often used to control erosion on difficult-to-revegetate areas, such as steep slopes. There has been some concern that flatpea may be toxic to cattle at certain times during its life cycle, but this characteristic has not been verified scientifically.

Sericea Lespedeza is used for revegetation on highways and mined lands to control erosion and to improve soil properties. Most lespedeza species are well adapted to infertile soils with low pH and low moisture availability. Stand establishment may be slow, but it may become the dominant species two to four years after seeding by forming dense, pure stands. Sericea can be an undesirable species in unmanaged land uses, because it is capable of crowding out other species. Pure stands often become a fire hazard in the fall. Unlike most N-fixing legumes, sericea does not provide much N to other plant species which are present. Procedures required to replace sericea with more desirable forage species on mined areas are reviewed in VCE Publication 460-119.

Because of sericea's ability to survive and prosper on low-fertility minesoils, it has been heavily utilized for reclamation in past years. The traditional varieties can be used effectively on extremely harsh sites, such as refuse banks. Due to the availability of numerous other species with more desirable characteristics, we recommend that reclamation of new mined areas with traditional varieties of sericea lespedeza be avoided.

Some varieties of sericea, however, can be used effectively as one component of a seeding mixture for a specific postmining land use on new mined areas. The Aulotan cultivar has a relatively low tannin content, making it more palatable to livestock than other cultivars. Even Aulotan should not be seeded in new reclamation unless there is a definite intent to utilize the land for livestock or regular hay production. Another lespedeza variety, Appalow, is low-growing and has proved to be compatible with other herbaceous vegetation, and

with the establishment of shrubs and trees.

Kobe lespedeza is a low-statured annual which can co-exist with other herbaceous vegetation, establishes rapidly, fixes N, and reseeds itself. As a warm season species, it grows best during the summer months, but is not competitive with grasses over the longer term on fertile soils. It has an upright form and a shallow rooting system. Kobe lespedeza can tolerate soil pH of 5 or below.

Sweetclovers, yellow and white, are used extensively in western reclamation due to their drought resistance and soil-building capabilities, and they have also been used in the eastern U.S. They are generally considered to be intolerant of acid soils. As biennials, the sweetclovers generally complete their life cycle in two years. On favorable sites, they will persist for longer periods as they reseed themselves.

Establishing N-fixing Legumes:

Establishing soil conditions that will allow legumes to persist is a major reclamation challenge. Most of the legume species commonly used by agricultural producers (such as the clovers and alfalfa) do not grow well under pH 6.0 (or below) soil conditions. Even if legumes survive a low soil pH, the N-fixing capability is often reduced because *Rhizobium* bacteria generally prefer soils with pH in the 6.0 - 7.5 range.

As "fresh" minesoils weather, the pH can change. Therefore, the long-term minesoil pH should be estimated based on materials that have been exposed to weather for at least one year, if possible. Proper liming and fertilization will enhance the ability of the seeded legume to become established, grow, and fix nitrogen. Legumes grow best in soils that are moderately well to well-drained, nonacid, and contain sufficient quantities of P and Ca. It is necessary to add lime and fertilizer when minesoil conditions are not favorable.

Several other factors are important to establishment of N-fixing legumes during reclamation. Too much N in the soil can inhibit N-fixing nodule formation and development. The amount of fertil-

izer N that inhibits N fixation varies among legumes, but generally ranges from 50 to 100 pounds per acre. When fertilizer is applied at higher rates, nodules may form but the effectiveness and efficiency of N fixation are decreased. During later years, as the inorganic soil N concentrations decline, the nodules can develop an increased capacity to fix N for the plant.

Legume Inoculation:

Inoculation of legume seeds with the appropriate strain of *Rhizobium* is an important seeding practice, especially where native *Rhizobium* are not present in the soil. Minesoils constructed from raw overburden will have a very limited native *Rhizobium* population. If the "topsoil" that is used to construct a minesoil has been stockpiled for an extended period, most or all of the native bacteria may have died. "Topsoils" that have been removed from forested areas will not contain substantial populations of *Rhizobium* bacteria, because plant species serving as Rhizobial hosts are not generally present in forests. In all of these cases, legume seeds should be inoculated with the appropriate strain of *Rhizobium* so that infection and nodule production will occur on legume roots.

The genus, *Rhizobium*, has seven strains based on the species of legume they infect. Table 4 shows the different strains of *Rhizobium* and the leguminous plants they infect. Because *Rhizobium* of one strain generally do not infect legumes outside of their infection group, seed inoculation with the appropriate *rhizobium* strain is essential if nitrogen fixation is to occur. If more than one legume is being seeded, the right strain of *rhizobium* bacteria must be present for each legume. Inoculum can be purchased from most seed suppliers (Figure 2). *Rhizobium* bacteria can only survive in packages for limited time periods; peat-based inoculum has a limited shelf life and should not be used after the expiration date. Inoculum should be kept cool and dry during storage. After the sealed inoculum package has been opened, the inoculum should not be exposed to direct sunlight and should be kept in a cool place.

Inoculation is the practice of adding effective

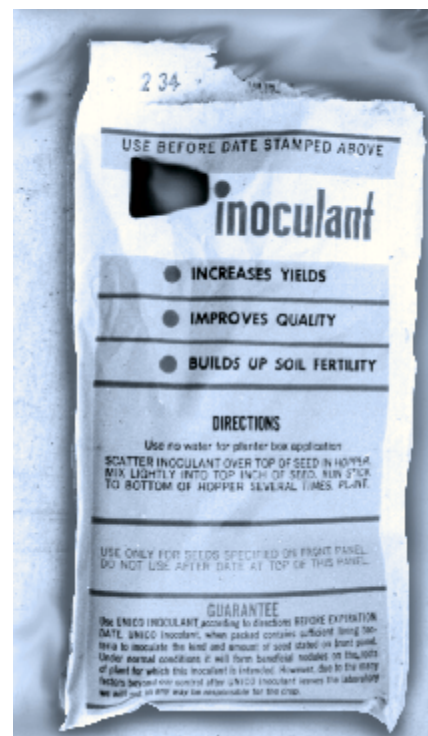


Figure 2. A package of legume inoculant purchased from a commercial seed supplier. Legumes can "fix" atmospheric nitrogen only if *Rhizobium* bacteria are present. Inoculant can be added to hydroseeder slurry, but precautions must be taken.

bacteria to legume seed before planting to assure adequate nodulation and promote nitrogen fixation. In agricultural practice, this is generally done by coating the seed with a water-based slurry (a mixture of a commercial preparation of bacteria with a peat carrier) just before planting. The carrier is enriched with sugars, gums, and polysaccharides to provide nutrition and protection to the bacteria, and to promote adhesion to the seeds. Because *rhizobium* bacteria are very sensitive to hot and dry conditions, inoculation should occur just before planting (within an hour) to decrease the length of time the inoculated seed is exposed to air and sunlight. There is a sharp decrease in bacteria numbers on seed as the time between inoculation and planting increases. It is also beneficial to plant into moist soil.

In mine reclamation, seed is typically applied with a hydroseeder. The seed and inoculum should be

Table 4. Strains of *Rhizobium* and the legumes they infect.

Strain	Legumes - Common Name (<i>Genus</i>)
<i>Rhizobium mililoti</i>	Alfalfa (<i>Medicago</i>), sweet clover (<i>Melilotus</i>)
<i>Rhizobium trifolii</i>	Clover (<i>Trifolium</i>)
<i>Rhizobium leguminosarum</i>	Field Pea (<i>Pisum</i>), Vetch (<i>Vicia</i>), Flat Pea (<i>Lathyrus</i>)
<i>Rhizobium phaseoli</i>	Beans (<i>Phaseolus</i>)
<i>Rhizobium japonicum</i>	Soybean (<i>Glycine</i>)
<i>Rhizobium loti</i>	Lupine (<i>Lupinus</i>), Trefoil (<i>Lotus</i>)
<i>Rhizobium</i> "Cowpea miscellany"	Cowpea (<i>Vigna</i>), Peanuts (<i>Arachis</i>), Lespedeza (<i>Lespedeza</i>), Crownvetch (<i>Coronilla</i>)

mixed together and put in the tank just prior to seeding, after the hydromulch, fertilizer, and water have been added, so as to minimize the amount of time the live bacteria must survive in the tank.

If hydroseeding is used to apply the reclamation seed mix, several precautions are in order. First of all, it is desirable to double the amount of inoculum that would be used to coat the seed in a nonhydroseeding application. Even more important, however, is the necessity of assuring that hydroseeder tank conditions and seeding practices will allow inoculum survival. Use of triple superphosphate (TSP) and other acidic fertilizers should be avoided when *Rhizobium* inoculants are mixed with the hydroseeder slurry, as TSP fertilizers can cause hydroseeder tank conditions to become so acidic that the bacteria will not survive. Because *rhizobium* bacteria are intolerant of acid conditions, it will be beneficial to add a small amount of lime to the hydroseeder tank mixture even when TSP fertilizers are not utilized. For more information on use of legume inoculum in hydroseeder slurries, see VCE Publication 460-105, *Legume Inoculum Survival in Hydroseeder Slurries*.

Revegetation Strategies

A variety of factors must be considered in a successful mined-land revegetation program. Soil properties, other site characteristics, the time of

seeding, the species seeded, and soil amendment application rates will affect revegetation success. When revegetation takes place on a mine site that is regulated under SMCRA, the postmining land use declared in the mining permit, and the degree of augmentation allowable within the five-year reclamation-success period, must also be considered.

Soil Properties:

The most effective way to achieve a "match" between soil conditions, species, and postmining land use is to select and place surface soil materials so as to create a soil that is favorable to vegetation that is compatible with the postmining land use declared in the mining permit (See VCE Publication 460-121).

Lime, fertilizer, and organic additions can be used to remedy problems of low soil fertility and/or moderate acidity. However, no amount of fertilizer or lime can remedy soil compaction, extremely coarse texture, and/or major chemical problems such as the presence of pyritic soil materials. Selection and placement of surface spoils will have a dominant influence over postmining land use vegetation success. A critical factor in evaluation of soil properties should be suitability for N-fixing legume species, most of which are more site demanding than grasses.

Postmining Land Use:

If the land is being prepared for reforestation, vigorous and competitive species such as tall fescue and sericea lespedeza should be avoided. (See VCE Publication 460-123).

Time of Seeding:

March through May, and late-August through October, are the best times to establish vegetation in southwestern Virginia and nearby areas, but seeding can be conducted successfully during most of the year.

Regardless of the season or month in which a regraded area is prepared for seeding, grass and legume species are available that should be compatible with site conditions. Cool-season grasses are best suited for seeding in late February to April, and September to early December. Some cool-season grasses, especially the winter annuals, can be seeded in most years as early as late January, but the success of mid-winter seedings will be weather dependent.

Many reclamationists feel that seeding in summer is a waste of time and material. However, experience and research provide examples of successful establishment of both temporary and permanent vegetation during the summer months. Warm-season grasses (especially the summer annuals) can germinate and establish under hot and dry conditions much better than cool-season grasses, but the summer grasses still require that some soil moisture be present. Rainfall during June, July, and August can be highly variable from year to year; moisture availability will be the primary factor affecting the success of summer seedings.

Rapid Vegetation Establishment:

Species that germinate, establish, and grow rapidly should be established to control erosion and stabilize the site. Annual grasses (such as foxtail millet, Japanese millet, pearl millet, oats, rye, annual ryegrass, or wheat) are often seeded to provide quick, temporary cover. The millets are often selected when seeding disturbed areas during

summer months (June-August), while cool season annuals are seeded during early spring and late fall. In addition, some perennial grasses also establish quickly on disturbed sites (i.e., redtop, perennial ryegrass, weeping lovegrass, and tall fescue).

A quick, temporary cover may be established by seeding with one, two, or several of the above species. A common practice in some areas is to seed permanent species (perennial grasses and legumes) into the mulch created by the temporary annual species either in the fall or spring following die-back of the annual crop.

One or more of the above quick-germinating species may also be included in a permanent-vegetation seeding mixture. The quick-germinating species will establish a vegetation cover rapidly while the perennial species - which are typically slower to become established - develop.

Mixed-Species Stands:

Most revegetation mixes will include several species of perennial grasses, and several species of N-fixing legumes. Annual grasses that act as a nurse crop may or may not be included.

There are many reasons for including multiple species in a seeding mixture. The presence of N-fixing legumes is essential to N-nutrition, while grasses tend to be more effective in controlling erosion. A variety of environmental conditions are generally found on reclaimed mine sites; the presence of a variety of species, each with its own site requirements, will help to assure successful revegetation of the entire site. Stands containing several species tend to be more productive over the long term than stands containing only one or two species, as multiple-species stands are able to utilize the full range of mine-site resources (moisture, light, nutrients) more effectively. The net result is that multiple-species stands are more like to achieve the "self-sustaining" status required by SMCRA.

Competition among species for moisture, light, nutrients, and space is an inherent problem when seeding more than three grass species in a mixture.

Usually one or two of the species in the mixture (especially the annuals) will germinate and become established more quickly than the other species.

Self-Sustaining Vegetation:

SMCRA requires establishment of self-sustaining vegetation. Under SMCRA, augmentation of revegetated areas with fertilizer, lime, or seed is not allowed within the five-year reclamation-success period for land uses where such augmentation is not a common management practice. Establishment of a self-sustaining stand of vegetation requires that several factors be considered.

First of all, the persistence of one or more N-fixing legume components is essential to long-term success. Nitrogen is a critical and necessary plant nutrient, and most mine soils contain no native, plant-available N. The legume components of the seed mix must be adapted to soil properties, and soil amendments should be applied as needed to establish an environment suitable for maintaining the legume species.

Secondly, organic matter and nutrient cycles must be established in the minesoil. In addition to shading and otherwise protecting slower-germinating perennials for a few months after seeds are applied, a fast-growing annual “nurse crop” grass can help to establish organic nutrient cycles. Fertilizer N, which would otherwise be leached out of the soil, can be taken up by the rapidly growing annual grass species. When the nurse crop dies back at the end of its annual cycle, the plant remains are decomposed by soil microbes and the released N can be taken up by perennial plant species.

Similarly, the P applied as fertilizer during revegetation will become unavailable to plants after several years time. “Blasted overburden” mine soils containing high levels of iron are especially prone to depletion of plant-available inorganic P, as fertilizer P tends to form insoluble complexes with soil iron (*i.e.*, it becomes tightly bound to soil particles, unavailable for plant uptake). A rapidly-growing annual grass nurse crop will take up fertilizer P from the soil early in the growth cycle.

As the annual grass dies and decomposes, the P becomes available for uptake by companion perennials.

Developing an organic matter “pool” or supply in minesoils is essential to successful reclamation. We recommend that hayland-pasture vegetation not be harvested during the first two years after seeding, so as to allow the plant remains to accumulate as organic matter in the soil. As it decays, this organic matter slowly releases nutrients that support the growth and development of a self-sustaining plant community.

Harsh Sites:

The practices discussed here will be adequate for the vast majority of mined sites. On harsh sites, such as those where surface spoils are extremely coarse textured, low in pH, contain pyrites, and/or are dark in color, additional measures may be called for. VCE Publication 460-131 contains recommendations for direct-seeding of vegetation on coal refuse; these practices may be adapted to reclamation of mine sites, if conventional revegetation practices prove unsuccessful due to harsh soil conditions.

Seeding Practices

Species and Application Rates

Most companies and seeding contractors use seed mixtures containing at least two or three perennial grasses, two or three legumes, and either a warm-season annual or a cool-season annual for quick cover. A wide variety of species are available for use in mined land reclamation (Tables 1 - 3).

An example of plant species and seeding rates for establishing a hayland-pasture postmining land use is given in Table 5. Some of the seeding rates are given as ranges. Generally speaking, poor site conditions would tend to favor seeding at rates near the upper end of these ranges. On the other hand, if all of the “optional” grasses and legumes are included in the mix and site conditions are not extreme, use of seeding rates at the lower end of each range would probably be successful. If a wide

range of site conditions are present on the area to be seeded, species adapted to a wide range of conditions should be included in the mix.

Selection of species and seeding rates should be based on species characteristics and site conditions. For example: Kobe lespedeza is a warm season species which would be beneficial on hot, droughty sites such as south-facing slopes; on the other hand, cool season species such as birdsfoot trefoil and redtop would be more beneficial at northern latitudes and high elevations. White clover, for example, grows best where soil pH exceeds 6 and adequate fertility is available. If such conditions are not present, legumes such as birdsfoot trefoil and red or crimson clover, which are better adapted to low fertility conditions, should be favored.

Purchasing Seed

Several terms that appear on seed labels can be useful when purchasing and applying seed, so as to reduce seeding costs.

The term “*viable seed*” refers to that portion of a seed lot that is capable of germination. Viable seed consists of two major components. Germination tests should have been conducted on the seed to provide a “percent germination,” and these test results must be printed on the label. In addition, that portion of the seed which did not germinate during a short-term germination test but will germinate over a longer term is also viable. The legume seed component known as *hard seed*, and the grass seed component known as *dormant seed*, should be added to the germination test results to determine viable seed content.

The term “*seed purity*” refers to the percentage of the seed lot that consists of the labeled species, as opposed to weed contaminants.

The percentage of a seed lot that is viable is calculated by multiplying the percent of pure seed (% Purity) by the germination percentage (% Germination plus percent dormant or hard) and dividing by 100 (Table 6). Grass seed commonly has moderate purity (60 to 80%) and high germination (> 90%). Legume seed commonly has high purity

Table 5. A typical seeding mixture for use by Appalachian mining operations on reclaimed areas that will be managed as hayland or pasture after mining, and where a variety of soil and site conditions are present.

Species	Seeding Rate (lbs./acre)	Comment
<u>Groundcover Grasses</u>		
Orchardgrass	10 - 30	
Tall Fescue	10 - 30	
Timothy and/or	5	Optional
Redtop	3	Optional
<u>Legumes</u>		
Birdsfoot Trefoil, and/or Kobe Lespedeza	5 - 10 ea	
Clovers	5 - 10 ea	2 or more species
<u>Nurse Crop</u>		
Millet or	20 - 30	Millet for shading during hot months; rye
Annual Rye	20 - 30	for quick cover in early spring or fall

Note: For reforestation or wildlife postmining land use, see VCE Publication 460-123.

(> 90%), low germination (< 50%), and a high percent of hard (dormant) seeds (20%). Low germination and high dormancy in legume seeds is explained by the complex seed coats that surround them. Blocking mechanisms within the seed are broken only when certain environmental conditions (temperature and moisture) or chemicals are applied to the seed coat, or the seeds are scarified.

Preconditioning seed in cool, moist conditions to promote germination is called *stratification*. Dormant seeds may germinate several years after the initial seeding due to natural stratification in the soil. Scarifying legume seeds may also help germination, but this is not a general practice in coal surface mine reclamation.

Quality should be considered carefully when purchasing seed that is offered for a low price. Referring to Table 6, the seed of Company A may be priced lower than the seed of Company B

because it has lower purity and germination. However, because of the difference in quality, a person could pay 10 to 20 percent more per pound for seed from Company B and still come out ahead.

Applying Seed with a Hydroseeder

In central Appalachia, surface mining generally requires reclamation of steep slopes. The most common technique for seeding and applying amendments is through a hydroseeder (Figure 3). Fertilizer, lime, mulch, and seed are normally mixed with water in the hydroseeder tank. Commercial cellulose mulch is typically included in the mix at rates of 1000 - 1500 lbs/acre. This material improves seed germination during dry weather and aids the hydroseeding process by marking seeded areas. Procedures for adding a legume inoculant, and assuring survival of that inoculant in the hydroseeded slurry, are discussed above. Fertilizer rates are discussed in VCE Publication 460-121.

Table 6. Calculation of purchased-seed application rates required to achieve desired rate of viable seed application, based on characteristics of seed provided by two hypothetical suppliers.

Supplier	A	A	B	B
Species	Tall Fescue	Birdsfoot Trefoil	Tall Fescue	Birdsfoot Trefoil
<u>Desired Application Rate</u>				
Viable Seed (lbs/acre)	20	10	20	10
<u>Label Information:</u>				
% Purity	90	80	95	90
% Germination	80	55	85	60
% Hard Seed	5	—	5	—
% Dormant Seed	—	10	—	15
<u>Calculated Quantities:</u>				
% Viable Seed	76.5	52	85.5	67.5
Application Rate (lbs/acre)	26	19	23	15

Conclusion

Success in establishing vegetation promptly and cost-effectively is the hallmark of successful mine reclamation and is essential to mine profitability. During the past 20 years, great strides have been made in developing effective mine revegetation strategies.

Two keys to successful revegetation are the selection and placement of a minesoil that is suited for the intended postmining vegetation, and the selection of plant species that are suited to both the postmining land use and the properties of that minesoil.

Success in revegetation on reclaimed mine areas is indicated by plant cover that is established rapidly, controls erosion, and persists through time. While each revegetation specialist has a favorite seeding technique, only a thorough knowledge of both minesoil properties and species characteristics will allow consistent and effective revegetation of surface coal-mined areas.

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Figure 3. A hydroseeder applying seed in a fertilizer slurry while revegetating a surface coal mine.

Powell River Project “Reclamation Guidelines”

This publication is a chapter from “*Reclamation Guidelines for Surface Mined Land in Southwestern Virginia*,” Virginia Cooperative Extension Publication 460-120, which is based on the results of research and education programs supported by the Powell River Project since 1980. Other Virginia Cooperative Extension publications referenced in the text are chapters of the *Reclamation Guidelines* series; all referenced chapters are in preparation but, as of this writing, some have not yet been issued.

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